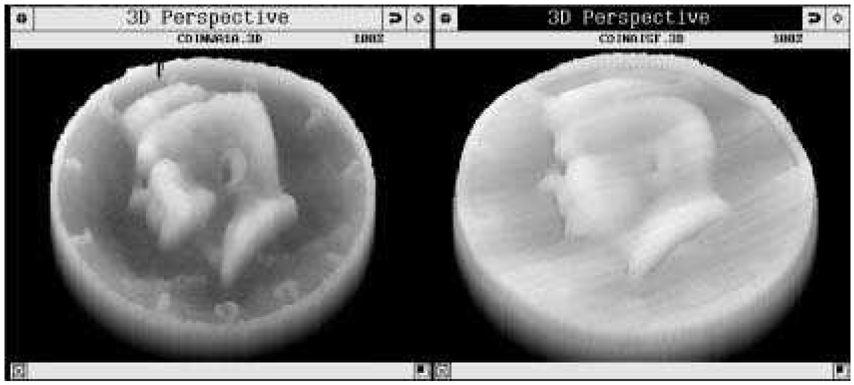
High-Frequency Focused Water-Coupled Ultrasound Used for Three-Dimensional Surface Depression Profiling



Water-coupled versus air-coupled ultrasonic surface profiling. Left: 25-MHz water-coupled, three-dimensional view. Right: 1-MHz air-coupled, three-dimensional view.

To interface with other solids, many surfaces are engineered via methods such as plating, coating, and machining to produce a functional surface ensuring successful end products. In addition, subsurface properties such as hardness, residual stress, deformation, chemical composition, and microstructure are often linked to surface characteristics. Surface topography, therefore, contains the signatures of the surface and possibly links to volumetric properties, and as a result serves as a vital link between surface design, manufacturing, and performance. Hence, surface topography can be used to diagnose, monitor, and control fabrication methods. At the NASA Glenn Research Center, the measurement of surface topography is important in developing high-temperature structural materials and for profiling the surface changes of materials during microgravity combustion experiments.

A prior study demonstrated that focused air-coupled ultrasound at 1 MHz could profile surfaces with a 25-µm depth resolution and a 400-µm lateral resolution over a 1.4-mm depth range. In this work, we address the question of whether higher frequency focused water-coupled ultrasound can improve on these specifications. To this end, we employed 10- and 25-MHz focused ultrasonic transducers in the water-coupled mode. The surface profile results seen in this investigation for 25-MHz water-coupled ultrasound, in comparison to those for 1-MHz air-coupled ultrasound, represent an 8 times improvement in depth resolution (3 vs. 25 µm seen in practice), an improvement of at least 2 times in lateral resolution (180 vs. 400 µm calculated and observed in practice), and an improvement in vertical depth range of 4 times (calculated).

In most cases, impressive topographical representations were obtained for all samples when they were compared with diamond-tip profiles and measurements from micrometers. The method is completely nondestructive, requires only water as a coupling fluid, and can

profile large areas limited only by the scan limits of the particular ultrasonic system. Using an optimized configuration, it is reasonably rapid and has all quantitative analysis facilities online including two- and three-dimensional visualization capability, extreme value filtering (for faulty data), and leveling capability. The most significant factor affecting practical utilization of the water-coupled ultrasonic method of surface profiling as described in this study is the scattering effect when high-frequency ultrasound encounters nonperpendicular surfaces and does not reflect back to the transducer. It was shown that in some cases, extreme value filtering with nearest neighbors averaging replacement algorithms can be employed successfully to obtain an accurate topological representation even in the presence of major scatter. Overall quantitative agreement, however, remains difficult in the presence of significant scatter.

The major advantage of ultrasonic surface profiling over more conventional profiling methods is its large area/high-speed capability and applicability to curved surfaces. The major disadvantage is it significantly reduced lateral and depth resolution capabilities in comparison with the conventional methods. This work was done at Glenn and at Sonix, Inc.

Bibliography

Roth, Don J., et al.: Using High Frequency Focused Water-Coupled Ultrasound for 3-D Surface Depression Profiling. NASA/TM--1999-209268, 1999. http://gltrs.grc.nasa.gov

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